Lameness assessment with automatic monitoring of activity in commercial broiler flocks

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ABSTRACT The possibility of using automatic recordings of broiler chicken activity in commercial flocks to assess the birds′ walking ability (lameness) was investigated. Data were collected from 5 commercial broiler farms in 4 European countries, using 16 flocks and 33 assessment occasions. Lameness was assessed using established gait scoring methods (Kestin et al., 1992; Welfare Quality®, 2009) and took place at 3, 4, and 5 wk of age. Gait score (GS) was used to assess the birds' walking ability, and automatic recordings of bird activity were collected using the eYeNamic™ camera system before, during, and after an assessor walked through the house. The variables used to predict the level of GS extracted from the camera system were: baseline activity, time from assessor leaving the house to resumption of baseline activity, average activity over that period, and Δ Amplitude (difference between highest activity peak after assessor left the house and baseline level). Age (<0.001) and Δ Amplitude ($P = 0.0002$) were significantly related to GS, with the gait getting poorer with increased age and Δ Amplitude decreasing with declining walking ability. Both measures are thus included in a predictive equation. The results demonstrate a potential method using image analysis techniques to realize an automated assessment of the level of lameness in commercial broiler flocks. This could be of use in future animal welfare assessment schemes.

Key words: gait score, precision livestock farming, image analysis, welfare

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INTRODUCTION

Broiler chickens, reared for meat production, have for decades been genetically selected for rapid growth and high meat yield and are reared intensively in large flocks with high stocking densities (Knowles et al., 2008). One consequence of this approach is an increased risk of lameness and impaired walking ability in the flock (Bradshaw et al., 2002). The breeding companies have noted the problem and 25 yr of selection to improve the leg health have been successful (Kapell et al., 2012), but still it is important to monitor the leg health in broiler flocks. Leg problems may have metabolic, developmental, or infectious causes (Butterworth and Haslam, 2009) and can impair the welfare of affected broilers (Bradshaw et al., 2002). Welfare is compromised because lame birds have problems accessing feed and water (Bessei, 2006) and they can experience pain (McGeown et al., 1999; Danbury et al. 2000; Caplen et al., 2013). Lameness is also negatively related to final weight at slaughter (Butterworth and Haslam, 2009) and may be associated with high flock mortality (Wideman et al., 2012). Several methods have been developed to assess lameness in broiler flocks. To determine the exact pathological cause of lameness, a postmortem examination of the bird is needed (Mench, 2004). Non-invasive methods include the latency to lie (Weeks et al., 2002) and the gait scoring method (Kestin et al., 1992, Welfare Quality®, 2009). In the former method, the bird's latency (delay) before it lies down is measured when birds are placed in a waterproof test pen with the floor covered with tepid water to depth of 30 mm; severe lameness results in short latencies, whereas birds with good leg health will remain standing for longer. This method provides an objective measurement of lameness but has time and resource constraints that limit the number of birds that can be tested. The "manual" gait scoring method is probably the most widely adopted; in this method, the bird's walking ability is graded between 0 (perfect walking) to 5 (not able to move). This observational method enables a large number of birds to be assessed during the same inspection, but

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it has been criticized for being subjective, having poor reliability among observers (Mench, 2004), and being costly in terms of the time, and, hence, the man hours required. Moreover, the risk for disease transfers when observers visit livestock houses should be reduced to a minimum. Developing assessment methods that can be conducted on-farm by the caretaker during daily routines can be one solution to the above mentioned issues, but also can reduce the stressful event of an unknown human enclosing and handling the birds (Marchewka et al., 2013).

Another approach that is a time-saving, continuous, and objective way to assess lameness could be provided by the use of currently available sensing technology to automatically evaluate and monitor walking ability in the broiler flock. Several experimental methods have been developed. Examples include use of force plates (Corr et al., 2007) or image analysis techniques, including the use of optical flow patterns (Dawkins et al., 2009). The eYeNamic^{TM} system (Fancom BV, Panningen, The Netherlands) uses video cameras and image processing methods (Kashiha et al., 2013) to monitor a relatively uncomplicated variable — the activity of a broiler flock. The eYeNamic^{TM} system was used to determine whether there were correlations between broiler activity and the level of lameness, using the gait scoreing method as a reference or "gold standard" (Aydin et al., 2010, 2013). A non-linear relationship was found (Aydin et al., 2010, 2013) in which birds with gait score 3 showed the highest levels of activity. These results suggest that general activity as such cannot be used to predict gait score in a flock (Aydin et al., 2010, 2013; Dawkins et al., 2009, 2012;). Therefore, in the current experiment, we decided to create a challenge, and induce movement of the birds by the presence of a human. An assessment was made of the activity measures before and after a human had walked through the flock, and it was then determined whether activity patterns observed around this human activity were related to gait score.

MATERIALS AND METHODS

Flocks and Farms

This experiment was conducted at 5 commercial broiler farms in 4 European countries (Italy, Spain, the Netherlands, and 2 farms in the United Kingdom). All regulations regarding ethical care and use of animals were strictly followed. In total, gait score data were collected from 16 flocks and 33 assessments occasions at the ages of 3, 4, and/or 5 wk (Table 1) while automated image based calculation of activity was carried out continuously over the entire rearing period. The farmers walked through the flock a minimum of twice per day, walking up and down each feeder and drinker row. The human-animal contact was mainly visual and the farmer examined the birds visually and removed sick or dead birds during the walk.

Table 1. Distribution of data collection

No. of farms	5
No. of flocks visited	16
No. of assessments	33
No. of assessments at age 3 wk	12
No. of assessments at age 4 wk	10
No. of assessments at age 5 wk	11

Measures

The birds′ walking ability was assessed using the gait scoring method presented in the Welfare Quality® protocols for poultry (Kestin et al., 1992; Welfare Quality®, 2009), in which the bird's gait is graded between 0 (perfect walking) to 5 (unable to move). At each assessment, 100 to 200 birds were randomly selected and a portable fenced arena was placed around the group of birds, using the procedures described in the Welfare Quality® protocol. Up to 5 groups were fenced at different locations in the house, which were distributed in a randomized fashion. All birds within a sampling pen were scored. The assessment scores were collected by trained assessors, one in each country, except in the United Kingdom where two trained assessors visited the farms.

Automatic activity recordings from the eYeNamic^{TM} system were collected with overhead cameras mounted on the ceiling. Only one camera was used to collect data in this experiment, and it was the one positioned close to the entrance. Recording began when the assessor entered the poultry house. The system enabled 3 measurements per minute. Activity was calculated as an index between zero (no activity) and 100 (all bird pixels have moved between 2 consecutive frames), based on image analysis technology (Kashiha et al., 2013).

Experimental Procedure

The experimental procedure started with the collection of baseline activity for 10 minutes. No disturbance was allowed in the broiler flock during this time. After 10 min, the assessor entered the animal house, walked along the side of the whole house, turned at the end, and walked back in a straight line through the middle of the house below the camera (see Figure 1). The aim was to mimic the way a farmer would move through the flock during the daily check of the animals, in a usual and more or less standardized way, and with a uniform moderate walking pace. The period when the human is present cannot be used within calculations, since the used eYeNamic^{TM} system does not differentiate between "human pixels" and "bird-pixels." Hence, the activity recordings when the human is in the house are a mix of bird and human movement. After the walking procedure, the flock was left alone without any disturbance for 15 min of activity recording. After this re-settling period, the assessor re-entered the house and gait scoring was carried out by fencing a groups of birds

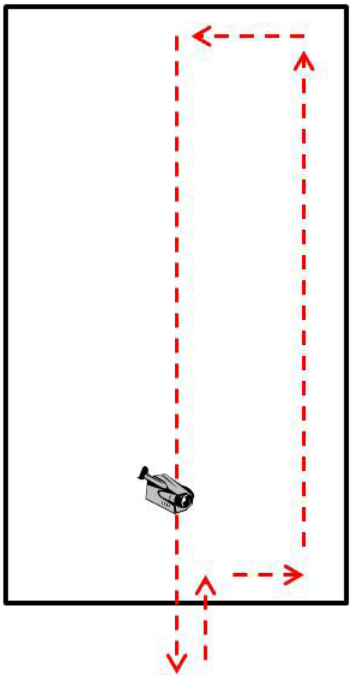

Figure 1. Standardized procedure of walking through the broiler flock.

(a total of 100 to 200 birds) and scoring the birds while they walked out of the arena.

Statistical Analysis

The variables calculated from the activity recordings are presented in Table 2.

The data sets were modeled using the multilevel statistical software package MLwiN (Rasbash et al., 2009). The multilevel structure of the data was specified within MLwiN as measurement occasion, within flock, within farm, whereas gait score was modeled using a GLM approach. Age, Δ Amplitude, baseline activity, average activity after, and time to return to baseline were all tested as covariates within the model. Those significant at $P \leq 0.05$ were retained in the final model (see Table 3), which can be used to predict the degree of lameness (gait score) in the flock. The statistical analysis resulted in the following predictive equation for GS:

$$\text{Gait Score}ijk = \beta 0\,ijk\,\text{const} + \beta 1\,\Delta\,\text{Amplitude}\,ijk + \beta 2\text{Age}\,ijk$$

RESULTS

Activity Recordings

Figure 2 describes the characteristics of the activity recordings. The period with the walking human is visible in the graph due to the increase and irregularity of the registered activity index. The reaction of the birds (Δ Amplitude) is visible as a peak in activity and a characteristic slope is shown when the birds recover from the disturbance and return to baseline activity levels.

Gait score

In general, gait score means showed little variation over time and all the flocks had low GS scores (3 wk = 1.4 ± 0.6, 4 wk = 1.5 ± 0.6, and 5 wk = 1.9 ± 0.6 [mean ± SD]), thereby showing good leg health status. The observed trend towards increased gait scores with increasing age was noted, and was expected (see Discussion).

Prediction of Gait Score Using Activity Index Recordings

An overview of the gait score and activity measures used in the statistical analysis are presented as mean values in Table 3.

Δ Amplitude and age were significantly related to gait score and are thus included in the equation. The levels of an effect (β), the standard errors, and P-values are presented in Table 4. The indices 'ijk' refer to the hierarchical levels: assessment occasion, flock, then farm, respectively.

Table 2. Variables derived from the activity recordings

Variable	Definition
Baseline activity	Average activity index during 10 min before the assessor entered
Time to return to baseline (s)	Time from when the assessor left the house to when the animals resumed baseline levels of activity
Average activity after	Average activity during the time to return to baseline activity
Δ Amplitude	The difference between highest activity peak after assessor left the flock and baseline level

Table 3. Mean values of gait score and activity measures presented by age

Age	Gait score	Baseline activity	Time to return to baseline	Average activity after	Δ Amplitude
3	1.4	6.29	388.25	9.67	17.22
4	1.5	6.28	368.70	9.01	13.24
5	1.9	5.82	391.91	7.28	7.57

Figure 2. Representative example of activity pattern of the broilers during the experimental procedure. The striped lines indicate when the assessor entered and left the stable.

Table 4. Parameter estimates from the model predicting GS from the automated activity measurements of the flocks (parameter estimates and *P*-values shown for the significant variables are estimates when the non-significant variables have been excluded from the model)

Variable	β	se	p-value
Constant	1.045	0.269	<0.001
Δ Amplitude	−0.011	0.003	<0.0002
Age	0.230	0.031	<0.001
Baseline activity	0.009	0.011	0.416
Time to return to baseline (s)	−0-00011	0.0000085	0.185
Average activity after	−0.001	0.011	0.927

DISCUSSION

The present study used a repeated, simulated, animal inspection routine in which a person walked through the flock to challenge the birds and elicit changes in their locomotor activity that could be automatically measured using the eYeNamic$^{\mathrm{TM}}$ system. The statistical analysis then determined if such activity changes were related to walking ability (lameness).

The variable Δ Amplitude, (which is a measure of the birds' direct response to an approaching human [moving away reveals their walking ability]), was significantly related to walking ability and might thus be used to predict the gait score level in a flock. Similarly, an earlier study found that Δ Amplitude and age were the strongest variables for predicting the human-animal relationship in a broiler flock (Silvera et al., unpublished data). Using the same methods as in this experiment the results from an avoidance distance touch test, in which the distance from an approaching human is assessed as a measure of fear of humans (Graml et al., 2008), could be predicted from activity recordings by the eYeNamic$^{\mathrm{TM}}$ system. It also can be considered that the Δ Amplitude can be related to birds moving away from the human as a response of fear of humans (Jones and Waddington, 1992). Since the method used in this experiment was designed as an imitation of the daily routine conducted by the farmer, the level of fearfulness was considered to be low due to habituation and thus not affecting the outcome.

The relationships presented in this study show promise for the future development of a fully automatic continuous assessment system. Since the model is directly fitted to the current data and experimental settings, it cannot be used to predict gait score as accurately as in this study in commercial broiler flocks as such. Its performance needs to be tested in more flocks in which the background variability may be greater. Both lameness and activity levels may vary among individual flocks and farms, which makes it desirable to test the method on a data set with a larger span of gait scores and activity levels. As in several automated tools in livestock monitoring, a self-adapting algorithm can solve these problems. Nevertheless, the results from this experiment show that there is a relationship worth further detailed study and that could be of potential for commercial use. The kurtosis and skew of the distribution of the activity data in this study would be interesting to add to future development of the method. In the study of Dawkins et al. (2012) positive correlations were found between the skew and kurtosis in optical flow data and gait score. The results showed that it could predict the gait score at 28 d, already several d beforehand. The experiment had, like the present study, a narrow range of gait scores (average score: 1.92 ± 0.23), which further advocates for the investigation of the correlations in future research. Further investigation of the skew and kurtosis of the data also is supported by the results by Roberts et al. (2012), in which Bayesian regression on continuous optical flow data predicted future gait score results in broiler flocks.

The birds' ages also had a significant and positive effect in predicting gait score. This is consistent with previous reports (Sørensen et al., 2000; Weeks et al. 2000; Kestin et al., 2001) and is likely a side effect of the very rapid increase in live weight with age.

Our finding that baseline activity measures had no significant effect probably reflected the fact that broiler chickens show low activity in general with 76 to 86% of the flock lying down (Weeks et al., 2000). However, measurement of baseline activity is necessary because it is included in the equation used to calculate Δ Amplitude. Furthermore, the age-related increase in lameness (Weeks et al., 2000) suggests that a more detailed on-farm study of general activity could be worthwhile.

CONCLUSION

The present results demonstrate the potential value of using image analysis techniques for automated assessment of lameness in commercial broiler flocks. The fact that the prediction of gait score was possible, even when the general leg health in the studied flocks was very good and had a narrow range (GS: 1.4–1.9), suggests future research to develop an automatic continuous on-farm assessment method.

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